Review of Restoration in Bottomland Hardwood Forests of the Lower Mississippi Alluvial Valley: Techniques and Functions/Values

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INTRODUCTION

More than three fourths of the land originally forested with bottomland hardwoods in the United States has been converted to other uses (Clewell and Lea 1990, Ouchley and others 2000), and the Lower Mississippi Alluvial Valley (LMAV) has sustained the most widespread loss of all. In addition to the loss of forested habitat to agricultural fields, flood control projects that separated the Mississippi River and its tributaries from their floodplains disrupted hydrologic cycles (Stanturf and others 2000, Sharitz 1992). Functions lost with deforestation of bottomlands and altered hydrology include timber production, habitat for endangered species and other plants and animals, export of detritus to estuaries, other food chain support, flood abatement, nutrient and pollution filtering and organic matter transformations which result in better water quality and sediment retention. Over the last 45 years, scientists at the Center for Bottomland Hardwoods Research at Stoneville, MS have developed artificial regeneration methods for bottomland hardwood tree species (Devall and Baldwin 1998, Stanturf and others 1998a). However, interest and attempts to restore bottomland hardwood forests in the LMAV have occurred only since the early 1990s. Functions of these restored ecosystems and services rendered by their replacement have been addressed only minimally (Clewell and Lea 1990, Sharitz 1992). The objective of this article is to give an overview/review of the history, values, functions, and restoration techniques available for LMAV bottomland hardwoods.

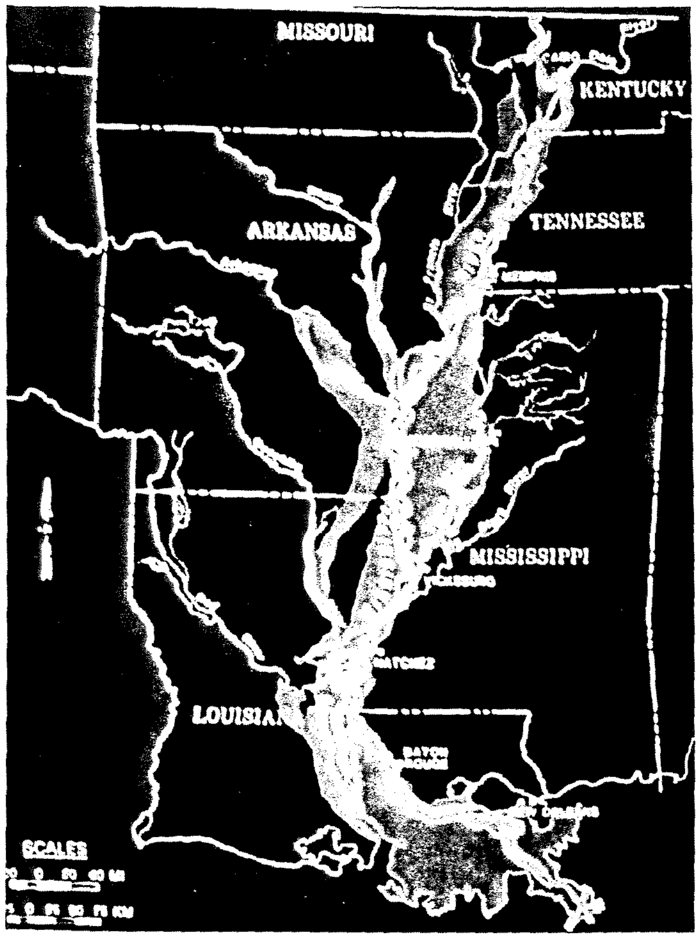


Figure 1. The Lower Mississippi Alluvial Valley extends from Cairo, Illinois to the Gulf of Mexico, and includes more than 24 million acres in seven states.

For some time ecologists have called for restoration and rehabilitation of damaged terrestrial and aquatic ecosystems (Cairns 1986, 1995, Jordan 1995), and recently restoration of degraded ecosystems has become a major focus within federal agencies (Stanturf and others 1998b). Forested wetlands that were converted for agriculture are being afforested through individual, corporate and governmental efforts (Twedt and Portwood 1997, King and Keeland 1999), although most of the restoration is occurring on federal land or through federal incentive programs (Stanturf and others 2000). For example, the Natural Resources Conservation Service, through the Conservation Reserve Program and the Wetlands Reserve Program is facilitating afforestation of former bottomland hardwood sites. Newer programs such as the Wildlife Habitat Improvement Program and the Environmental Quality Incentives Program aid in these efforts. Additionally, the U.S. Army Corps of Engineers mitigates losses of forested wetlands due to its flood control projects. Game management on these mitigation areas is often transferred to state wildlife agencies.

HISTORICAL BACKGROUND

The LMAV includes more than 24 million acres (9.7 million hectares) in seven states, from southern Illinois to the Gulf of Mexico (Figure 1), and contains the largest expanse of forested wetlands in the United States. The woody vegetation of the region is diverse and the forests may contain as many as 70 commercial tree species (Putnam and others 1960) as well as numerous vines, shrubs and herbaceous species (Carter 1978, Wiseman 1982, Meadows and Nowacki 1996). Differences in soil type and depth, and duration and frequency of flooding result in various forested wetland species associations (Penfound 1952, Putnam 1951).

An estimated 21-24 million acres (8.5-9.7 million hectares) of bottomland hardwoods existed in the Valley before European colonization began (The Nature Conservancy 1992, Turner and others 1981). The original acreage may have been greater since Native Americans may have cleared some of these forests for agriculture (Hamel and Buchner 1998). It is commonly believed that oaks were the dominant species in presettlement forests, but Ouchley and others (2000) suggest that sweetgums (*Liquidambar styraciflua*) were the predominant trees in mature bottomland hardwood forests in Louisiana.

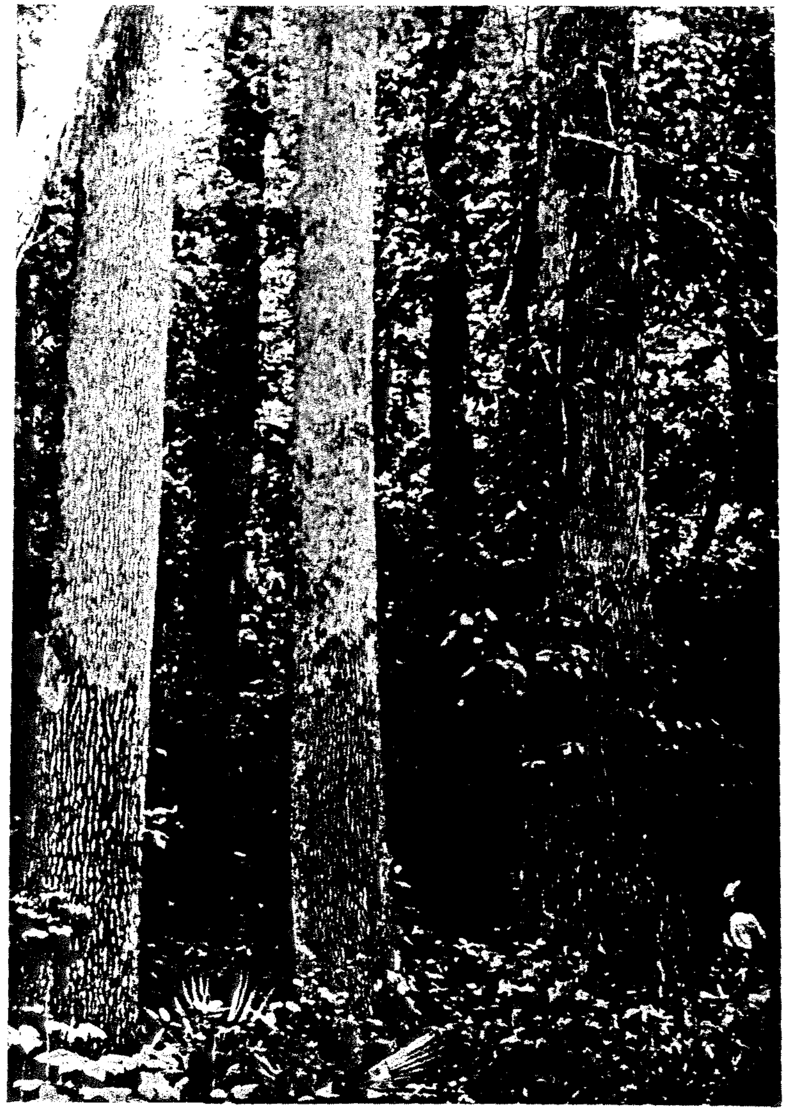


Photo 1. The Red Gum Research Natural Area, a remnant of old growth bottomland hardwood forest in the Delta National Forest, Mississippi.

At the time of European colonization, wetlands were considered useful only after they were drained. The Swamp Land Acts of 1849-1850 granted federally owned swamplands to the states for reclamation and disposal. Practically all of the loss of bottomland hardwood forests has been due to agricultural conversion (MacDonald and others 1979). Approximately half of the original forests were cleared between 1800 and 1935. During the 20th century, flood control projects straightened and deepened rivers, drained swamps and made clearing of wetter sites feasible. High soybean (Glycine max (L.) Merrill) prices during the 1960s-70s led to a large increase in forest clearing (Sternitzke 1976). For example, 90 percent of the woodlands cleared in Arkansas during the 1960s were planted in soybeans (Holder 1972). The net economic return on farmland at that time was reported to be twice as high as that on forests (Turner and Craig 1980). By 1991 only 23.3 percent of the 18th century forest remained (The Nature Conservancy 1992). Later, as commodity prices fell, agricultural land that was subject to spring and summer backwater flooding became less profitable to farm. Some of this economically marginal land is now available for afforestation (Stanturf and others 1998a).

Since the passage of the "swampbuster" provisions of the 1985 farm bill, clearing of forested wetlands for agriculture has declined (Shepard and others 1998). Most of the remaining bottomland hardwood forests in the southern United States are in Louisiana, Mississippi and Arkansas (Photo1). The Atchafalaya Basin in Louisiana is the largest contiguous tract of bottomland forest (MacDonald and others 1979, The Nature Conservancy 1992).

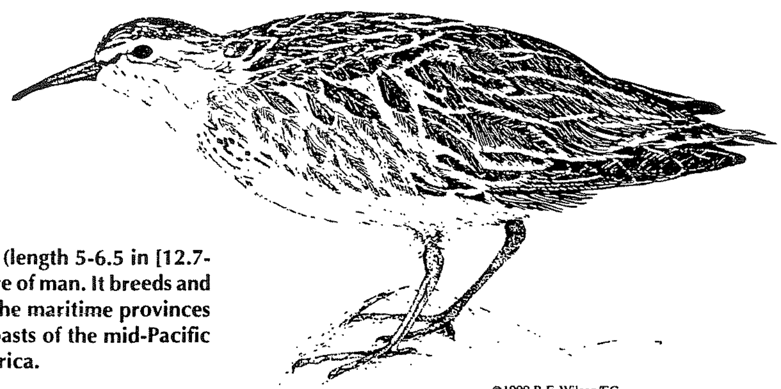
WETLAND FUNCTIONS AND SOCIETAL VALUES

Wetlands functions are the normal or characteristic processes that take place in wetland ecosystems (Smith and others 1995). Values refer to benefits, the goods and services accruing to the society as a result of the functions that wetlands perform (Brinson and Rheinhardt 1998). When wetlands are restored to any level, increases in functions should occur. Assessments can be carried out to determine if functions at a site increase or decrease over time. A review of 40 wetland assessment procedures currently used throughout the United States is provided by Bartoldus (1999). It is important to measure impacts to wetlands using functional assessment rather than values assessment. Most wetland evaluation procedures did not differentiate between or provide separate measures for each function and value. These distinctions are necessary, otherwise, low measures may be assigned and result in a decision to alter or destroy a high functioning wetland (Brinson and Rheinhardt 1998). For example, concentration of interest on the fertile soil of wetlands in the LMAV has led to their draining and clearing for agriculture.

Forested wetlands in the LMAV provide a variety of functions, including sediment retention, sinks for pollutants and excess nutrients, and production of bottomland hardwood and cypress timber (*Taxodium distichum* [L.] Richard). Bottomland species improve air quality because trees in the wetlands filter particulates from adjacent areas (Clewell and Lea 1990, Brinson and Rheinhardt 1998). They export organic material, which contributes to fresh water and estuarine food chains that sustain shell and fin fisheries. Bottomland hardwood swamps also provide habitat for numerous aquatic and terrestrial wildlife species (Dickson 1991, Hamel 1992, Wilson 1995). Forested wetlands help abate and control floods because the trees provide resistance to flowing water and the wetlands can retain some floodwater and storm water runoff, thereby reducing flood peaks. Stored water can contribute to stream flow, recharging local groundwater supplies, and to increased soil moisture during dry seasons. Forested wetlands provide habitat for plants and terrestrial animals, fish and shellfish, including some rare and endangered species, such as pondberry (*Lindera melissifolia* [Walt.] Blume), the grass-of-Parnassus, (*Parnassia grandifolia DC.*), the Louisiana black bear (*Ursus americanus luteolus*) and Bachman's warbler (*Vermivora bachmanii*). They are used as rookeries by wading birds (Clewell and Lea 1990), for example, wood storks (*Mycteria americana*) and yellow-crowned night herons (*Nyctanassa violacea*). The existing wetland forests in the LMAV are important wildlife habitats. Bottomland hardwood forests are preferred habitat for many animal species and produce high quality food and browse (Kellison and others 1998). The principal goals of forest restoration programs in the Valley have been to create wildlife habitat and improve or protect surface water quality (Stanturf and others 2000).

TYPES OF BOTTOMLAND HARDWOOD FOREST RECOVERY

Wetland recovery can include marsh or forest. In either case, the project can entail creation or restoration. Most wetland recovery projects have involved restoration of marshes, which can be successfully replaced within a few years (Clewell and Lea 1990, Kolka and others 1998b). In contrast, bottomland forest replacement takes decades, since reestablishing forest canopy requires 20 years or more. For the first few years, young trees, such as oaks (*Quercus spp.*), grow along with brush and weedy herbs and comprise only a small portion of the vegetation of a mature bottomland hardwood forest (Clewell and Lea 1990). After 5-10 years, at around 13.12 ft (4 m) in height, the oaks will develop a significant 3-dimensional



least sandpiper
Calidris minutilla

The least sandpiper is the smallest of the North American shorebirds (length 5-6.5 in [12.7-16.5 cm]). It is quite common and noted for its tameness in the presence of man. It breeds and nests in the low Arctic tundra from Alaska to Labrador or in bogs in the maritime provinces of Canada. In the winter the least sandpiper can be seen along the coasts of the mid-Pacific mid Atlantic, and Gulf coast states and coastal regions of South America.

In addition to being found feasting in ocean tidal areas in their winter range, they are common along muddy margins of brackish ponds and creeks. In addition to feeding on beach fleas, they commonly eat mosquito larva, crickets, and bloodworms.

(see reference 1 and 4 on page 37)

structure. Canopy closure may not occur for 20 years or longer, even if faster growing species have entered the site (Twedt and Portwood 1997).

In the southeastern U.S., bottomland forest creation is carried out mainly in central Florida where surface mining for phosphate has occurred. Wetland creation involves building a wetland on an upland site or former upland site (e.g., surface mine). In these projects, the physical site attributes as well as the vegetation must be generated. Some projects on surface-mined land have involved recreation of headwater streams and their forests, while others planted a forest on the reclaimed edges of pit-mine lakes and surrounding marshes. In the early projects, containerized bottomland hardwood trees were planted, but in later projects, undergrowth and trees were restored (Clewell and Lea 1990).

Most bottomland forest restoration projects have occurred on economically marginal agricultural land in the LMAV. The purpose has usually been to establish a forest canopy of selected tree species, especially of oaks and other species with heavy seeds and limited dispersal. The soils are mostly intact and the main task is to regenerate the forest (Clewell and Lea 1990). Since the floodplains have been separated from the Mississippi River and its tributaries, hydrologic cycles are no longer intact. Some local hydrologic restoration is a stated program goal of the Wetland Reserve Program (Lockaby and Stanturf, in press). This is an important goal of wetland restoration. In many wetlands converted to agriculture, the local hydrology has been altered as the fields have been leveled and drainage ditches have been inserted. Simply plugging the drainage ditches is seldom sufficient because the fill from the ditches has been placed on the fields. The slough, oxbows, depressions and wind throws that are common in even minor bottoms have been eliminated. Moreover, in most areas, flooding is changed in terms of duration, depth and sediment load (amount and composition) in the flood waters. Hydrology can be manipulated prior to attempting restoration. The factor most critical for the success of all recovery projects is to attain sufficient hydrological conditions (Clewell and Lea 1990). Consequently hydrology verification is necessary in these undertakings (Garbisch 1990).

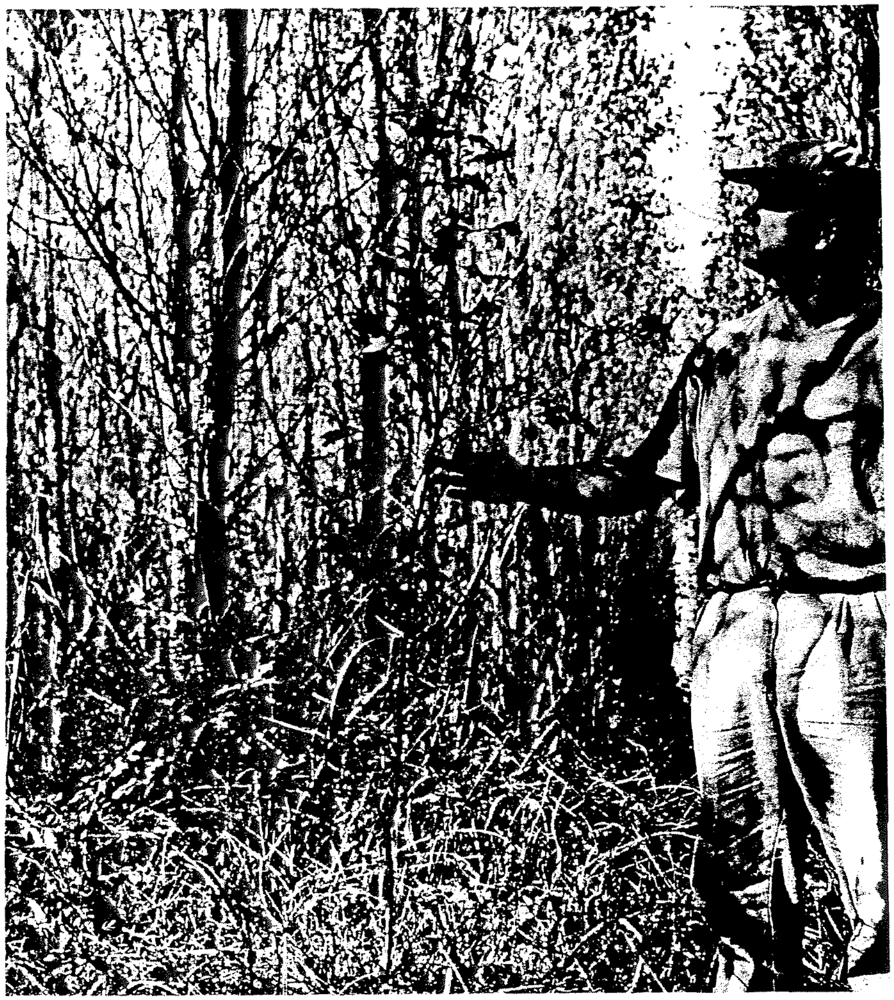


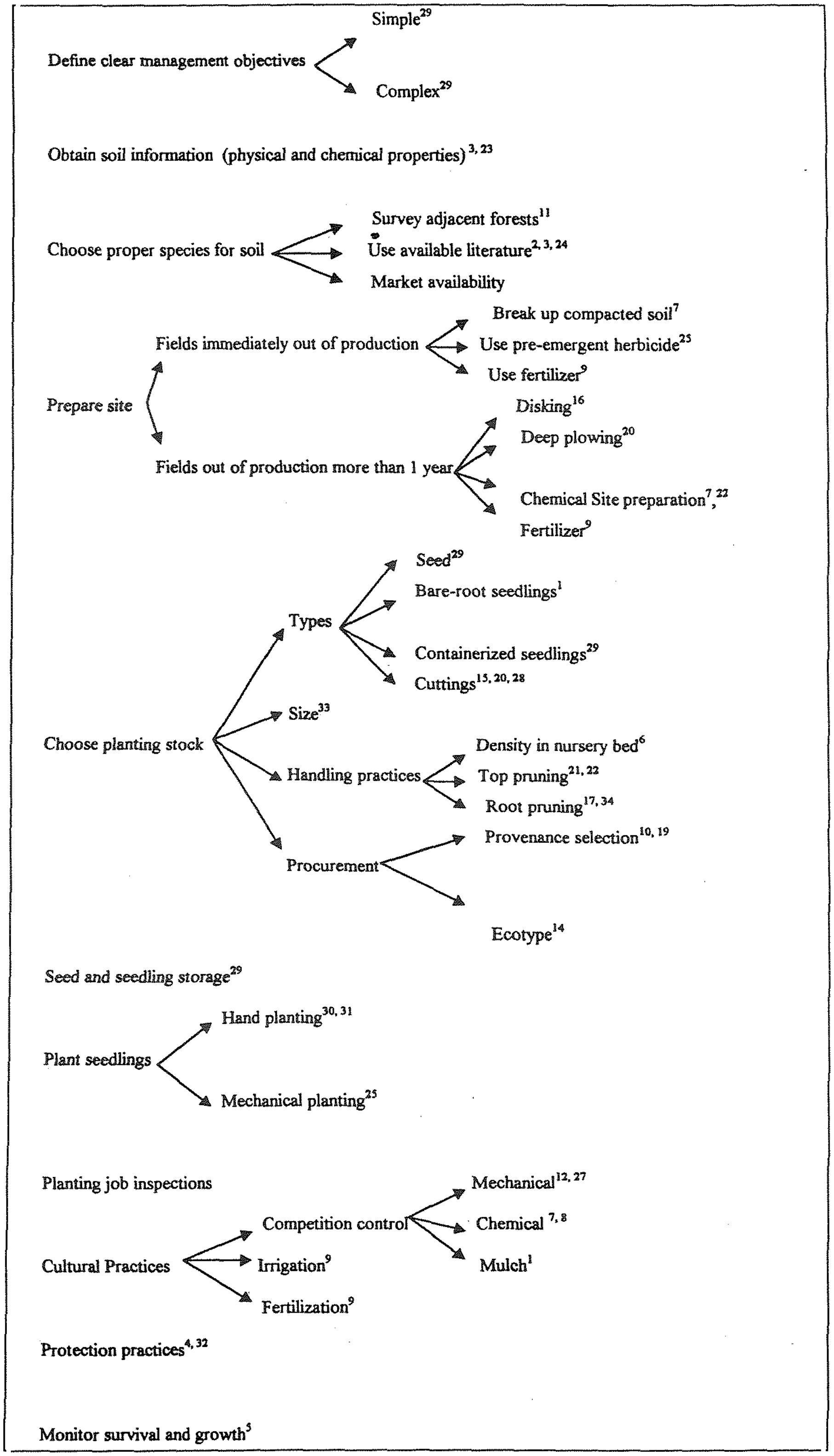
Photo 2. Three-year-old Nuttall oak (*Quercos Nuttalli* L.) interplanted in an eastern cottonwood plantation established on a former agricultural field in Sharkey County, MS.

Wetland restoration is more likely to be successful than creation of a wetland at an upland site because at former wetland sites, at least some of the necessary hydrologic factors are still intact, some seed of wetland plants may be available, and fauna may migrate from adjacent areas (Kusler and Kentula 1990).

TECHNIQUES

Different techniques may be necessary to restore specific functions/values. An objective of many landowners is to improve the value of the land for recreational hunting, so they choose tree species such as oaks that provide food for game species. Different tree species, spacing, planting schedule, etc. may be chosen if the objective is to improve the value for non-game wildlife. If one objective is to restore the function of habitat for birds, planting a nurse crop of a fast-growing species, such as cottonwood, followed by a slower-growing species (Photo 2), quickly provides a forest that is attractive to neotropical migrant birds (Twedt and Portwood 1997). Bartoldus and others (1994) provide techniques for evaluation of six major wetland functions during the planning process to determine whether the planned restoration project will achieve the desired function goals.

Table 1. Techniques for restoring bottomland hardwood forests on former agricultural land.



[1]Adams 1997, [2]Baker and Broadfoot 1979, [3]Broadfoot, 1976b, [4]Conner and others 1999, [5]Curtis 1983, [6]Dey and Buchanan 1995, [7]Ezell and Cachot 1998, [8]Ezell and others 1999, [9]Francis 1985, [10]Green and others 1991, [11]Groninger and others 1999, [12]Houston and Buckner 1989, [13]Johnson and Krinard 1985, [14]Keeley 1979, [15]Kennedy 1977, [16]Kennedy 1990, [17]Kennedy 1993, [18]Land 1983, [19]McKnight 1970, [20]Meadows and Toliver 1987, [21]Miller 1993, [22]Natural Resource Conservation Service county soil series manuals, [23]Putnam and others 1960, [24]Russell and others 1998, [25]Schweitzer and others 1999, [26]Schweitzer and Stanturf 1999, [27]South 1998, [28]Stanturf and others 1998a, [29]Stanturf and others 2000, [30]Stanturf and Madsen in press, [31]Strange and Shea 1998, [32]Thompson and Schultz 1995, [33]Toliver and others 1980

Publications by Allen and Kennedy (1989), Gardiner and others (in press), and Stanturf and others (1998b) provide detailed reviews and afforestation guidelines for bottomland hardwood tree species. These publications highlight the various aspects of afforestation including planning, species assignments, site preparation, planting and sowing methods, seed and seedling procurement, handling and storage, and post-planting operations (Table 1). When planning forest regeneration projects, it is of vital importance for the landowner to explicitly define management objectives (Gardiner and others ,in press). Without well defined management objectives, critical decisions regarding the various aspects of afforestation cannot be adequately addressed. Current research is focused on developing alternative afforestation techniques that will provide landowners with cost effective options for targeting various objectives including timber production, game and non-game wildlife habitat production, carbon sequestration, water quality improvement, and others. Site preparation is especially important on former agricultural land, and typically results in increased survival and improved early growth (Gardiner and others, in press, Russell and others 1998, Ezell and Cachot 1998).

It is most important to match the species to the site. Few species can withstand continuous flooding, and in addition, soil physical conditions, root aeration, nutrient availability and moisture availability are important (Putnam and others 1960, Baker and Broadfoot 1979, Broadfoot 1976a). Oaks have been the species most often planted because of their value as wildlife food and for timber and because it was thought that lighter-seeded species would naturally seed. Tree seedlings cost more than seeds, but their survival is more reliable, and a larger number of species is available. Some cultural and seedling handling practices, such as top pruning of hardwood seedlings, root pruning, and low nursery bed densities can improve performance especially on harsh sites. Although ecotype has usually been ignored in the LMAV, the use of seed collected from other regions and site types could reduce establishment success, productivity and forest health (Gardiner and others, in press).

Seedlings must be handled with care, and should not be allowed to dry out during transportation. Dormant bareroot seedlings should be planted into moist soil, into a planting hole large enough so severe root pruning is unnecessary (Stanturf and others 2000). J-rooting (bending the seedling root to fit in the planting hole) should be avoided and the planting hole should be filled, leaving no air spaces (Johns and others 1999). Seedlings should be protected from subfreezing temperatures at planting, and protected from high temperatures (Stanturf and Madsen, in press, Stanturf and others 2000). The best time for planting is January-March (Clewell and Lea 1990). Some tree species grow well from cuttings, including cottonwood (*Populus deltoide* Bartr. ex Marsh), willows (*Salix spp.*), sycamore (*Platanus occidentalis* L.), green ash (*Fraxinus pennsylvanica* Marsh), and sweetgum (McKnight 1970, Kennedy 1977, Stanturf and others 1998a).

If seeds are used, they must not be handled carelessly. Acorns are the seeds that are most often planted. Acorns of the red oak group can be stored for up to two years, while white oak acorns can only be stored for four months. Species that have been successfully established on an operational scale include: red oak species *Q. nigra* L., *Q. phellos* L., *Q. shumardii* Buckl., *Q. pagoda* Raf., *Q. nuttallii* Palmer, white oak species, *Q. lyrata* Walt., *Q. michauxii* Nutt., persimmon (*Diospyros virginiala* L.), and pecan (*Carya illinoensis* (Wang) K. Koch) (Johnson and Krinard 1985, Stanturf and others 1998a, Gardiner and others, in press). Late spring flooding that covers seedlings for some time, or an exceptionally dry spring can lead to low survival. Deer (*Odocoileus virginianus*) and other mammals may destroy seedlings (Stanturf and others 2000). Tree tubes or shelters can protect seedlings against herbivory (Allen and Boykin 1991, Allen 1995). Alternative site preparation techniques can be employed, such as planting directly under shrubs, to minimally alter early successional vegetation and protect seedlings from herbaceous competition by species such as blackberry (*Rubus spp.*) and from herbivory. Greater damage by herbivores often occurs in open areas (Kolka and others 1998a,b).

COSTS

Restoration on public lands in the LMAV has usually involved introduction of oaks and other heavy-seeded species used by wildlife. Oaks can be regenerated by direct seeding or by planting seedlings. On some sites, wind and water may disperse light-seeded species and increase stocking. Direct seeding acorns costs less than planting bareroot seedlings ($76 per acre for site preparation, seed material and sowing) but is less likely to be successful. Low density plantings (12 x 12 ft spacing or wider) of 1-0 (one year in the nursery and no years in a transplant bed) bareroot seedlings per acre, intended to produce 125 stems of hard-mast species per acre at age 3, cost $126. This is a relatively wide spacing. More intensive plantings with a target of 250 seedlings per acre at age 3, and including weed control for two years, cost $170 or more per acre (Table 2).

Cost-benefit analyses of post-planting cultural practices are not available, but the costs may be justified if they prevent plantation failure, due to herbivory or drought, for example (Gardiner and others, in press). In some areas, control of invasives may be necessary. For example, Chinese tallow (*Sapium sebiferum* [L.] Roxb.), a woody invader of wetlands in the southeastern United

Table 2. Typical direct costs per acre for afforestation of bottomland hardwoods in the Lower Mississippi Alluvial Valley.

	Direct-seeded oaks[1]	Low-intensity bareroot seedlings[2]	High-intensity bareroot seedlings[3]	Interplanted cottonwood and oaks[4]
Site preparation				
Disking	$16.00	$16.00	$16.00	$16.00
Preemergent herbicide			$ 13	$13.00
Rip and mark				$15.00
Fertilize				$15.00
Planting				
Material (varies by spacing)	$25.00	$75.00	$75.00	$60.00
Planting	$35.00	$35.00	$35.00	$20.00
Year 2 planting oak seedlings				$56.00
Weed control				
Herbicide (banded around seedling/6 ft [1.83 cm] swath)			$11.00	$11.00
Mechanical			$10.00	$20.00
Insecticide (spot spraying)				$9.00
Year 2 weed control			$10.00	$10.00
Total	$76.00	$126.00	$170.00	$245.00

Note: Numbers based on actual costs for material and labor in 1999. Table adapted from Stanturf and others, 2000.

[1]Suitable oaks are direct-seeded at 12 by 3 ft spacing (1,211 stems per acre [spa]) with target survival of 125 spa at age 3.

[2]*Low intensity planting is typical of national wildlife refuges and the Wetlands Reserve Program; trees are planted at 12 by 12 foot* spacing or wider (302 spa) with a target of 125 stems per acre surviving at age 3.

[3]High intensity planting is needed for timber production: 12 by 12 ft planting (302 spa) and a target of 250 spa at age 3; survival is assumed to be double that of low-intensity planting because of weed control.

[4]*Cottonwood is planted at 12 by 12 ft spacing (302 spa); to get a survival rate of 80 to 95 percent requires 1 to 2 years of weed* control. The oak seedlings are interplanted after one or two years of weed control. The oak seedlings are interplanted after one or two growing seasons between every other row of cottonwood at 12 by 24 ft spacing (151 spa). Cottonwood can be coppied to provide income from a second rotation before the oaks are released.

States, produced 22,600 seedlings ha^{-1} in a preserve in east Texas (Bruce and others 1997).

RESTORING THE UNDERSTORY

Among key functions of forested wetlands are maintenance of biotic diversity and wildlife habitat (Clewell and Lea 1990) and for many restorationists afforestation by itself is insufficient (Stanturf and others 2000). Most of the plant species that are found in bottomland hardwood forests are herbs, shrubs, vines and small trees. For example, Devall (1982) found 22 tree species, 4 small tree and shrub species, 11 vines and 51 herbaceous species at Cat Island Swamp in southeastern Louisiana. In most restoration efforts, the undergrowth has been ignored or has been expected to occur through natural regeneration (Clewell and Lea 1990, Zedler and Weller 1990). Common wisdom holds that wooded areas will recover on their own and less conspicuous species will return once a canopy has developed, but this is not true for many plant and animal species. Herbaceous species that are poor dispersers may require reintroduction or habitat restoration (Bratton and Meier 1998). Annual disturbance of agricultural lands removed buried seed and destroyed perennial plants. Furthermore, limited seed dispersal on large tracts, dense herbaceous competition and low light levels in the young forest may reduce establishment of many understory species.

Wildlife, including bird species, is likely to be more diverse in wetlands with several vertical layers. Mammals, amphibians and reptiles are also distributed vertically in the forest (Bartoldus, Garbisch and Kraus 1994). If a landowner wishes to improve the function of the forest as habitat for diverse plant and animal species, understory and midstory species can be planted, but little research or guidance exists on reliable establishment techniques. Not much is known about the tolerance of native understory species to shade, competition or flooding (Kolka and others 1998a). Some authors suggest that gaps can be created or left during planting to facilitate natural seed dispersal into the restoration forest (Allen 1997, Otsamo 2000), but the efficacy of this approach has not been demonstrated for bottomland forests. Restorationists in Australia found that increasing levels of intervention increased the likelihood of restoring understory species diversity (Yates and others 2000). Tree planting could be done over multiple years to produce a more diverse structure, and not an even-aged forest, although this would add to the cost of restoration. If natural invasion is expected to regenerate the understory and midstory, there must be seed sources within dispersal range (Chapman and Chapman 1999). Restoration of micro relief (mounds, swales and drainage channels) could enhance the area and aid in restoring the understory by providing microsites to which understory species are best adapted. Logging and agriculture remove large woody material and may eliminate microhabitats suitable for species that may establish on fallen logs (Bratton and Meier 1998).

RECOVERY OF RARE AND ENDANGERED SPECIES

Bottomland hardwood forests provide the important function of wildlife habitat, including habitat for some endangered species (Clewell and Lea 1990) and the restoration of this function is often a goal of bottomland hardwood restoration projects. Loss and degradation of the bottomland hardwood habitat could cause serious problems for wildlife, especially birds that utilize this resource, since the plant species that inhabit bottomlands and uplands are so different (Knutson and Klaas 1998). There is an excellent opportunity improve the value of damaged ecosystems for rare, threatened or endangered species by restoring favorable habitat (Cairns 1986). Plants, seeds or cuttings can be used, but if they are not available, tissue culture can provide plants of rare species for restoration. This method was used to supply plants of five rare and endangered species for reintroduction to a scrub habitat in Florida (Kent and others 2000). An expensive method for introducing understory species, if plants are not otherwise available, is transferring topsoil from a donor forest (Clewell and Lea 1996, Roberts 2000). Yet another strategy is to plant fast-growing trees to provide perches for frugivorous birds, which disseminate the seeds of some plants and enhance diversity (Twedt and Portwood 1997).

For the past three years, scientists at the Center for Bottomland Hardwoods Research have been working on the recovery of pondberry (*Lindera melissifolia* [Walt] Blume), an endangered shrub that occurs in forested wetlands (Devall and others, in press). During fall 2000, pondberry propagules were transplanted to areas in three national wildlife refuges and a state park in Mississippi, where the habitat was suitable (Photo 4). Pairs of potted plants (usually 10 pairs/site, 2 or 3 sites/area) are planted and enclosed with 4 ft (1.3 m) tall wire fencing to prevent herbivory. The transplants are watered during dry seasons. It is too early to judge the final success of the project, but plants are growing well at present. It appears that pondberry will be a good candidate for introduction to restored bottomland forest habitat.

BENEFITS OF RESTORATION

Most benefits of restoration accrue to society as a whole. Landowners receive incentive payments to offset loss of revenue from farming but under current USDA programs, opportunities for timber management are limited by the understocked stands that result from cost-sharing planting under the Wetland Reserve Program (low intensity planting). Restoration planting that results in 125 stems per acre at age three will limit timber management as well as manipulation of the stand for wildife habitat or other uses (Stanturf and others, 2000). However, the proper combination of private landowner participation and entrepreneurship along with government incentive programs could offer landowners and land managers in the LMAV some unique opportunities to help reduce the global accumulation of carbon dioxide through afforestation of agricultural lands that may or may not be productive.

Anthropogenic inputs of so-called 'greenhouse' gases such as carbon dioxide, methane, and oxides of nitrogen

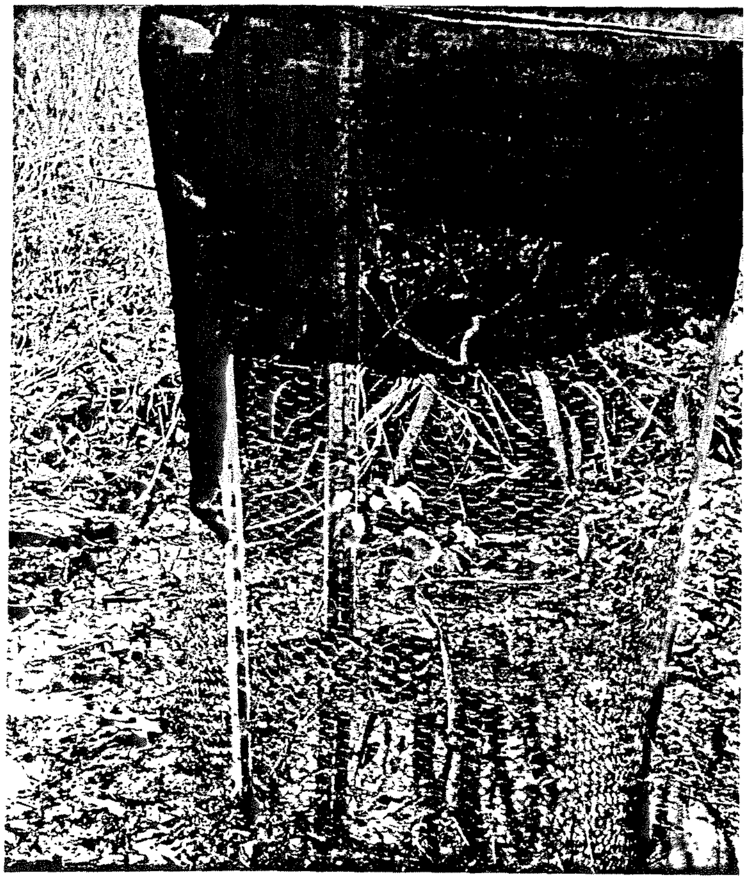


Photo 4. Pondberry (*Lindera melissafolia* [Walt.] Blume) plants introduced to suitable habitat in a protected area.

in the atmosphere have for some years been steadily increasing above apparently normal, historic levels (Ning and Abdollahi 1999). Some research suggests that these increased greenhouse gas concentrations are affecting global surface temperatures by altering the amount of solar energy reflected off the Earth's surface—the 'greenhouse effect' (Ning and Abdollahi 1999). There are numerous hypotheses and process models that attempt to explain changes in climate and the subsequent effects to natural and man-made ecosystems (National Assessment Synthesis Team 2000). Whether warranted or not, concern about deleterious effects of increased emissions on the environment has led many of the world's countries to agree, at least in principle, to reduce emissions of greenhouse gases to several percentage points below their 1990 levels by about 2010 (Ning and Abdollahi 2000).

Currently, there are about 5 million acres of the original approximately 24 million acres of bottomland hardwood forest in the LMAV. The majority of these former forests were cleared to grow annual crops, especially soybeans. Previously uncleared land often characterized by clay soils and periodic flooding, which is generally less suitable for farming, was cleared to take advantage of high soybean prices. Now, these areas are marginally profitable at best, and landowners are looking for other uses for their land, especially if it involves a good return on their investment. Substantial amounts of carbon can be tied up in wood tissue for years by planting trees on abandoned or unproductive agricultural land. Carbon sequestration rates in one study ranged from 16 kg/yr (35 lb/yr) for small, slow-growing trees to 360 kg/yr (800 lb/yr) for larger trees growing at their maximum rate (Jo and McPherson 1995). Recently, a pilot trading market for carbon emissions was established, the Chicago Climate Exchange, which has the potential to become a market-based mechanism by which carbon sequestration credits are exchanged for carbon emissions (ENS 2001). Further research is needed to determine formulas for growth and yield of various tree species on different sites, and to develop optimal cultural, silvicultural, and economic systems that will help make afforestation a worthwhile endeavor for private and public interests in the LMAV.

ENVIRONMENTAL

Restoration provides environmental benefits including flood control, decreased soil erosion, improved air and water quality and reduced pesticide use. Restored bottomland forest is also valuable as wildlife habitat or for timber production (Twedt and Portwood 1997). Avifauna respond to the increasing complexity of vegetation in restoration areas. For many insectivorous neotropical migratory birds, the three-dimensional structure of the forest may be more important than the tree species that have been planted because it provides more niches for breeding birds (Twedt and Portwood 1997, Hamel and others, in press).

Stream bank stabilization and water temperature moderation are other environmental benefits of reforestation (Groninger and others 2000). Water quality benefits of restoration occur as a result of soil stabilization by wetland plants and eliminating tillage. Former uses of restored land involved soil disturbance (tillage) and considerable erosion. Some filtering, retention, and assimilation of nutrients and farm chemicals from surface runoff and ground water may occur (Stanturf and Madsen, in press) if local hydrology restoration has been successful. In most cases, however, this will be less than typical of floodplain wetland forests (Lockaby and Stanturf in press). Large-scale hydrologic restoration that would fully restore structural and functional attributes of the systems are not really feasible today because of the widespread alteration that has occurred and because of economic constraints (King and Keeland 1999). The effects of human activities, such as construction of roads, have a great potential to alter hydrology and consequently biogeochemical functions, but there is a lack of data on these and other human influences on wetlands (Lockaby and Wallbridge 1998, Lockaby, Stanturf and Messina 1997).

RECREATIONAL

Recreational benefits derived from restoration of bottomland hardwood forests are usually the result of creating and enhancing wildlife habitat. Recreational hunting for deer and turkeys (*Meleagris gallopavo*) as well as waterfowl will be enhanced if oaks are planted (Twedt and Portwood 1997). Bird watching will be enhanced and the landowner and society as a whole will derive benefits from the existence value of wildlife (Stanturf and Madsen, in press).

FINANCIAL

Financial returns to landowners as a result of restoration could eventually include income from hunting leases and potential payments for carbon sequestration (Stanturf and Madsen, in press). Income from timber production is doubtful except under CRP where a cottonwood nurse crop is planted (Stanturf and Portwood 1999; Stanturf and others 2000).

PROBABLE FUTURE TRENDS IN RESTORATION

Ecosystem functions and services rendered will likely be subject to more careful assessment in the future. A few wetland assessment procedures were developed with the increase in wetland protection in the 1970s, but they focused on a limited number of functions and values. Numerous approaches for identifying characterizing or measuring wetland functions have been developed to meet needs during the 1990s (Bartoldus 1999). For example the WET-BLH (Adamus and others 1990) was developed for bottomland hardwoods in the southeastern United States. Even more refined techniques will likely be developed in the future. Provision should be made to introduce undergrowth (herbs, shrubs, understory trees) as well as canopy tree species. Emphasis on oaks probably will decrease, (Stanturf and others 2000) partly because widely spaced oak plantings are not resulting in a diverse bottomland hardwood forest (Allen 1997). A more intensive strategy should used on private land, which will provide wildlife benefits and restore a forest of complex structure (Twedt and Portwood 1997, Stanturf and others 1998a, b). In addition to recent efforts, projections indicate that additional restoration of bottomland hardwood ecosystems in the LMAV is possible. If current funding levels continue, around 500,000 acrescould be restored in the coming years.

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Cardinal flower
Lobelia cardinalis

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